CLOSED MIXER WORKING PROCESS, WITH STROKE CONTROL RAM

The present invention generally relates to the processing of polymer compounds and mixtures in a mixer of the closed type.

This kind of processing is commonly performed in the manufacture of tyres or components thereof such as tread bands and the like; such processing consists of mixing a polymer base together with other ingredients according to predetermined recipes, in order to obtain semi-finished products to be used in the subsequent phases of the manufacturing cycle.

Closed mixers, also known as discontinuous mixers, are substantially formed by a mixing chamber accommodating a pair of rotors rotating in mutually opposite directions, wherein the material is loaded in predefined quantities (batches) and processed by the rotors which completely discharge it from the mixer at the end of the cycle, before beginning to process a new batch of material.

In this connection it should be considered that the term “mixture” in this description is intended to indicated the generic intermediary product obtained during any phase of the processing cycle, while the term “compound” will be used to refer to the semi-finished product derived from the addition of the cross-linking system to the mixture in order to prepare it for subsequent vulcanization.

The chemical-physical characteristics of the mixtures and the compounds, which allow an end product with desired qualities to be obtained, depend also on the processing in the closed mixers; for this reason the control of this operating phase has a decisive role in the manufacture of tyres and their components.

The process variables which influence the working process in closed mixers are many and it is therefore difficult to ensure an adequate control thereof throughout the whole operating cycle, i.e. from the filling of the mixer to its emptying.

Examples of these process variables are the characteristics of the ingredients used for compounds and mixtures, their temperature, the speed and the torque applied to the rotors, the filling level of the mixer (i.e. the so-called "fill factor") and others.

Nowadays various mixing control systems are known, which are based on the detection over time of certain process parameters (also called "indirect" parameters), such as the temperature of the mixtures or the energy conferred to the system, and on the eventual correction thereof by modifying other parameters (also called "direct" parameters) which directly determine the functioning of the mixer, such as, for example, the speed of the rotors, the pressure of the pressing ram and so on.

Examples of this procedure are described in international patent application No. PCT/US98/23294 and in US patent No. 4,830,506.

In particular the latter describes a system for controlling processing in a closed mixer, based on regulating the pressure of the pressing ram so as to ensure that when the ram is in the lowered operating position, it can oscillate with a small predetermined amplitude (in the order of half an inch, i.e. approximately 12.5 mm).

According to this US patent, with such a control system it is possible to obtain an improved mixing action by making use of the periodic rebounds due to the rotation of the rotors.

One characteristic of compounds and mixtures which, until nowadays, closed mixers and their regulating systems did not control efficiently, is the dispersion of the various ingredients within the processed mass.

This characteristic is of considerable importance for obtaining an end product with the required qualities, both because a non-homogenous dispersion of an ingredient in the mixed material can cause local defects in the tyre or semi-finished product which will be manufactured, and because a different dispersion between one charge of material processed in the mixer and the subsequent one, can result in lack of uniformity between "batches" with the same basic formulation and can negatively influence the repeatability of the rheometric curve of the compound.

The present invention aims at providing a method for regulating the working process in a closed mixer, which allows a better and more constant dispersion of the ingredients in the processed mass to be obtained.

The invention arises from the Applicant's perception that said dispersion also depends on the profile of the position over time of the pressing ram, during the phase of incorporation of the materials in the polymer matrix.

The invention applies preferably, but not exclusively, to the incorporation phase of the reinforcing filler in the polymer; as "reinforcing filler" is intended here both the carbon black commonly used in the manufacture of tyres and the so-called white fillers with their optional bonding agents.

Said fillers are ingredients of the inorganic type such as gypsum, talc, kaolin, bentonite, titanium dioxide, alumina, various silicates and silica, which are used for tyre compounds in order to increase grip in the wet conditions, reduce the rolling resistance of the tyre and other purposes.

The invention also applies to the addition of the crosslinking system to the mixtures in order to obtain compounds to be vulcanized, as well as to the mixing of mixtures having different compositions and, more generally, whenever it is required to combine the polymer matrix with substantially solid material introduced into the mixer during processing.

According to the invention, the downward stroke of the ram after the introduction of the material into the mixer is performed by controlling the descent position-time profile thereof during the incorporation phase in the polymer, in such a way as to follow a predetermined reference pattern: this allows to achieve a controlled position of the ram, which gives time to the rotors for mixing the ingredients before the ram reaches the working condition at the end of its stroke.

The term "position-time profile" in this description and in the following claims, is intended to refer the profile over time of the position of the pressing ram; said profile can easily be represented graphically, by plotting in a Cartesian plane the position of the ram on the ordinate and the time on the abscissa.

Further features and advantages of the invention will emerge more clearly from the description given here below with reference to the accompanying drawings,

of a preferred but non-exclusive embodiment thereof.

In particular, the first figure of the drawings shows a mixer of the closed type for carrying out the method of the invention.

Figure 2 is a graph showing the profile over time of the position of the pressing ram, during a working cycle according to the invention.

Figure 3 is a graph showing the profile over time of the power applied to the mixer and the operating pressure of the pressing ram, during the same working cycle of Fig. 2.

Figure 4 is a table showing the position of the pressing ram as a function of time, during the phase of incorporation of the filler in the polymer matrix which takes place in the processing cycle of Figures 2 and 3.

Figure 5 shows an explicative graph of the effects, on dispersion, of the method according to the invention.

Last, Figures 6 and 7 are the rheometric curves of compounds processed, respectively, with the method of the invention and according to the prior art.

With reference to the first figure, the mixer 1 shown therein is of the so-called "Banbury®" type which comprises a pair of tangential rotors 2 and 3 rotating in opposite directions inside a mixing chamber 4, cooled by water circulating in a series of channels 5, 6.

The mixer 1 comprises the pressing ram 8 fixed to the end of a rod 9 actuated by a pneumatic (or hydraulic) cylinder 10.

The mixer 1 is further provided, for introduction inside it of the material to be processed, with a lateral hopper 11, whereas discharging of the processed mixtures or compounds takes place from below, through an opening present in the base of the mixing chamber 4 and closed by an obturator device 12.

In the mixer 1 the position of the pressing ram 8 and the rod 9 which actuates it is detected in a way known per se with transducers, not shown in the drawings; according to the invention said position is detected throughout the whole stroke of the

pressing ram, from the raised (resting) condition thereof in which it allows charging of the material via the hopper 11, to the lowered (working) condition.

As lowered (working) condition is intended the distance between the point at which the pressing ram meets the compound and the lowest point that can be reached by said ram, depending on the filling level of the mixing chamber and on the physical characteristics of the compound being processed. These two extremes are respectively called the upper and lower end-of-stroke positions.

In this way it is possible to determine the downward speed of the pressing ram throughout its stroke and to regulate said speed, as will be explained more clearly hereinafter, by means of the general control system of the mixer which for this purpose comprises electronic means (of the PLC type and the like) known per se.

The graphs in Figures 2 and 3 refer to the processing of a typical mixture for compounds reinforced with silica, whose the composition is given below by way of example, specifying the ranges of variation for each ingredient and expressing the quantities in “phr”, i.e. parts by weight for each 100 parts of polymeric material:

Polymer base	100
Carbon black	0-80
Silica	10-80
Bonding agent (of the silica)	4%-15% of the silica
Zinc oxide (ZnO)	1-3
Stearic acid	0-3
Anti-deteriorating agents	1-3
Plasticizing oil	0-30
Anti-ozone wax	0.5-3
Specific chemical ingredients	0-15

In order to obtain the compounds, it will be necessary to add to these ingredients the crosslinking system in the usual quantities according to the composition of the mixture; said system is preferably composed of sulphur (from 0.5

to 2.5 phr) and vulcanization accelerators.

The polymer base can be any polymer or mixture of polymers, either of natural or synthetic type, suitable to assume all the chemicophysical and mechanical characteristics of the elastomers after appropriate crosslinking.

Preferred polymer bases include polymers or co-polymers with an unsaturated chain, obtained through the polymerisation of conjugated dienes and/or aliphatic or aromatic vinyl monomers.

In the example referred to in Figures 2 and 3, the polymer mass weighs 113.7 kg (with a dry content equal to 94.08 kg) and is mixed together with a reinforcing filler comprising, in addition to carbon black, silica.

The overall weight of the reinforcing filler is 68.2 kg, wherein the silica constitutes 58% which is bonded to the polymer base by means of known elements such as silane.

In the example, the processed mass also comprises 8 kg of free oil and 21.15 kg of other ingredients present in smaller percentages such as, typically, silane or other bonding agent of silica, zinc oxide, stearic acid and anti-deteriorating agents, in such a way as to obtain a fill factor of the mixer equal to 67.7%.

The latter is defined by the ratio between the mass present in the mixer (211 kg in the example) and the capacity of the mixer (equal to 270 litres) multiplied by the density of the aforementioned mass (1.154 kg/dm^3).

The processing cycle referred to in the graphs of Fig. 2 and 3, is divided into successive phases which can be identified from the time on abscissa.

In this way at the start, the rotors 2 and 3 of the mixer 1 are brought up to a predetermined average speed of 40 revolutions/minute, for the initial introduction of the ingredients into the hopper 11 (interval from 0 to 2 min. about); in this condition the pressing ram 8 is fully raised to allow the passage of the ingredients towards the mixing chamber 4.

Once the loading phase has been completed, the ram 8 is lowered: this

operation is performed by controlling the pressure applied by the actuating fluid (oil or gas) on the pressing ram, in such a way as to follow a predetermined absolute position-time.

The subsequent positions of the ram as a function of time (calculated in seconds from the start of the descent of the ram) are summarised in the table in Fig. 4, and the data relating thereto is shown in graphical form in Fig. 2.

As can be seen, in this example initially the descent occurs very quickly (over 1,250 mm in 6 seconds), until the ram meets the mass of the ingredients introduced into the mixer.

At this point, control of the pressure applied by the operating fluid on the pressing ram is initiated, as a function of the position thereof: the ram begins therefore to descend in gradual manner with a controlled feed movement of 90 mm in 45 seconds.

In this connection it is worth to explain that reference is made to an average forward movement of the ram, because the real movement thereof is characterised by successive oscillations (visible in the diagram of Fig. 2) caused by the mass introduced into the mixing chamber, which is subject to a periodic movement imparted by the rotation of the rotors that superposes to the downward linear movement of the ram.

The position of the latter is regulated by adjusting the pressure of the fluid in the actuating cylinder 10; this regulation is controlled by the mixer control system, which in this phase regulates the pressure applied to the pressing ram and causes said ram to move downwards with a predetermined position profile, whose gradient (i.e. the degree of displacement per unit of time) is set out in the recipe.

In this way the position over time of the ram is used as a process control parameter, in addition to those parameters already known, such as temperature, pressure applied to the pressing ram, power, etc.

The abovementioned position also supplies information on the compaction

curve of the material which, as is known, is correlated to incorporation of the polymer in the chamber.

In this manner it also becomes possible to identify the optimum time for addition of the plasticizing ingredients, following incorporation of the filler.

When the pressing ram 8 reaches the working condition, mixing of the mixture proceeds according to the usual criteria which will depend in each case on the semi-finished product to be obtained.

The graph in Figure 2 shows the position-time profile of the position of the ram for an operating cycle; said position is expressed as a distance in millimetres (mm) from a predetermined reference point, which in this case is the lowered working condition, while the time is in minutes.

Figure 3, on the other hand, shows the graphs of the pressure applied to the pressing ram for actuation thereof and the instantaneous power used by the rotors, during the same operating cycle of Fig. 2; the units of measurement are psi for pressure, kW for power and minutes for time.

As can be seen, in the phases subsequent to that of introduction of the ingredients considered above, the ram is raised and lowered quickly between the upper and lower end-of-stroke positions, because the further introduction of other material to be mixed is not sheduled; however, this possibility should not be excluded and in such a case, lowering of the ram will still be performed in controlled manner likewise already explained.

The results obtained with the processing method according to the invention have been rather favourable.

Indeed, upon performing laboratory tests on mixture samples according to the above example (using the reflected light technique and the "Dispergrader 1000" system made by Optigrade), it was possible to ascertain that the dimensions and the number of aggregates present in the processed mass were lower with respect to a mixture obtained with the same process in which, however, lowering of the pressing

ram did not take place in a controlled manner according to the teaching of the invention.

For this purpose, reference is made to the graph in Figure 5 obtained on the basis of the aforementioned tests, where the ordinates show the number of aggregates having a specific average diameter, shown on the abscissas.

As can be seen, the curve relating to the mixture processed according to the invention has for each average diameter value a number of aggregates which is systematically lower than that of the mixture processed normally, i.e. without control of the descent of the pressing ram.

Furthermore, with the method according to the invention aggregates with an average diameter greater than 50 μm are almost completely eliminated.

Of course variations of the invention with respect to what has been described hitherto, are possible.

In the first place it is necessary to point out that the processing method considered can be used in all mixers of the closed type (for example also those with intermeshing rotors) provided with a pressing ram.

Furthermore, as mentioned above, control of the downward stroke of the pressing ram must not be regarded as applicable only to dispersion of the reinforcing filler, but can also be performed during all the processing phases which require dispersion of other materials in the polymer mass, such as the addition of the crosslinking system to the mixtures in order to obtain compounds to be vulcanized, or the mixing of mixtures of different compositions carried out by adding one of them to the mixture already present in the mixer, and so on.

However, implementation of the method according to the invention in relation to the reinforcing filler is particularly advantageous because, in addition to the improved dispersion already mentioned above, it also allows addition of the plasticizing substances to be optimised.

In this respect it is necessary to point out that in the prior art, since the phase

of incorporation of the filler is performed without controlling the position of the ram and with the use of conventional parameters such as temperature, energy and power, execution thereof occurs over a predetermined time span (typically in the region of 1 min.), at the end of which it is assumed that incorporation is completed.

The result is that, without any control, the ram can reach the working condition either before or after the abovementioned time span.

In the first case a loss of specific power occurs: this means that there is a dead time which could be used to add the plasticizing substances, but which is not used for this purpose because there is not sufficient certainty that incorporation of the filler has finished.

By lowering the ram controlling its position over time on the basis of a predetermined feed speed as in the present invention, it is possible to ensure that the incorporation of the filler finishes exactly when the ram reaches the lowered working condition, so as to bring it back into the raised resting condition afterwards and introduce the plasticizers.

In the second case, on the other hand, since the ram reaches the working condition too late, a loss of material can occur as a result of the suction when said ram is raised to start the subsequent processing phase, for example cleaning thereof or the introduction of plasticizers.

In both cases mixing of the processed material is affected.

The consequences of this situation are shown in Figure 7 compared with Figure 6. They show the rheometric curves relating to compounds according to the above recipe being obtained by controlling the pressing ram with the method of the present invention (Figure 6) and operating in accordance with the prior art (Figure 7).

As can be seen, while in the case of the method of this invention the various curves plotted on the graph in Fig. 6 have a rather uniform trend, in the case of the prior art (Fig. 7) there is a certain dispersion of the values obtained.